

PATENT COOPERATION TREATY

PCT



INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference PCT-2784	FOR FURTHER ACTION		See Form PCT/IPEA/416
International application No. PCT/KR2005/000369	International filing date(day/month/year) 07 FEBRUARY 2005 (07.02.2005)	Priority date (day/month/year) 10 FEBRUARY 2004 (10.02.2004)	
International Patent Classification (IPC) or national classification and IPC G21C 9/016(2006.01)i			
Applicant KOREA ATOMIC ENERGY RESEARCH INSTITUTE et al			

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 3 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
 - a. ☒ (sent to the applicant and to the International Bureau) a total of 12 sheets, as follows:
 - ☒ sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
 - ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.
 - b. ☐ (sent to the International Bureau only) a total of (indicate type and number of electronic carrier(s)) _____ containing a sequence listing and/or tables related thereto, in electronic form only, as indicated in the Supplemental Box relating to Sequence Listing (see Section 802 of the Administrative Instructions).
4. This report contains indications relating to the following items:
 - ☒ Box No. I Basis of the report
 - ☐ Box No. II Priority
 - ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
 - ☐ Box No. IV Lack of unity of invention
 - ☒ Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
 - ☐ Box No. VI Certain documents cited
 - ☐ Box No. VII Certain defects in the international application
 - ☐ Box No. VIII Certain observations on the international application

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INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.

PCT/KR2005/000369

Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

- ☒ This report is based on translations from the original language into the following language English which is the language of a translation furnished for the purposes of:
- ☐ international search (under Rules 12.3 and 23.1(b))
 - ☒ publication of the international application (under Rule 12.4)
 - ☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the **elements** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

- ☐ the international application as originally filed/furnished
- ☒ the description:
 pages 1-2, 4, 6-7, 13 as originally filed/furnished
 pages* 3, 5, 8-12, 14-15 received by this Authority on 12 May, 2006
 pages* _____ received by this Authority on _____
- ☒ the claims:
 pages _____ as originally filed/furnished
 pages* _____ as amended (together with any statement) under Article 19
 pages* 16-18 received by this Authority on 12 May, 2006
 pages* _____ received by this Authority on _____
- ☒ the drawings:
 pages 19-22 as originally filed/furnished
 pages* _____ received by this Authority on _____
 pages* _____ received by this Authority on _____
- ☐ the sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing.

3. ☐ The amendments have resulted in the cancellation of:

- ☐ the description, pages _____
- ☐ the claims, Nos. _____
- ☐ the drawings, sheets _____
- ☐ the sequence listing (*specify*): _____
- ☐ any table(s) related to sequence listing (*specify*): _____

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).

- ☐ the description, pages _____
- ☐ the claims, Nos. _____
- ☐ the drawings, sheets _____
- ☐ the sequence listing (*specify*): _____
- ☐ any table(s) related to sequence listing (*specify*): _____

* If item 4 applies, some or all of those sheets may be marked "superseded."

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.

PCT/KR2005/000369

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-9	YES
	Claims	None	NO
Inventive step (IS)	Claims	1-9	YES
	Claims	None	NO
Industrial applicability (IA)	Claims	1-9	YES
	Claims	None	NO

2. Citations and explanations (Rule 70.7)

The present invention relates to an apparatus for passively coolin and retaining molten core material, comprising a molten core material retention tank, a compressed inert gas tank, a cooling water storage tank, and a means for mixing the inert gas and the cooling water.

Reference is made to the following documents from the international search report.

D1 : JP 4-286994 A

D2 : US 4382907 A

D1 discloses a containment vessel cooling apparatus comprising water and inert gas.

D2 discloses a liquid metal cooled nuclear reactor including a main storage tank for receiving liquid metal and inert gas.

None of the above documents anticipate the separate molten core material retention tank supplied with the mix of inert gas and cooling water, or makes it obvious to a person skilled in the art.

Accordingly the subject matter of claims 1 through 9 appears to be novel and to involve an inventive step. (Article 33(2) and 33(3) PCT)

The industrial applicability of the subject matter of claims 1 through 9 is self-evident. (Article 33(4) PCT)

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As shown in FIG. 2, the conventional apparatus has a plurality of molten core material catcher parts 130 installed below a reactor vessel 100. In the apparatus, molten core material discharged from the reactor vessel 100 during a severe accident in a nuclear plant is retained in the molten core material catcher parts 130, and the retained molten core material is cooled by cooling water 120 filled around the molten core material catcher parts 130.

However, the above-described apparatus cools the molten core material of high temperature by bringing the molten core material into indirect contact with the cooling water. Accordingly, heat transfer efficiency between the molten core material and the cooling water is low and thus a very large cooling water tank is required.

Also, there has been proposed an apparatus for actively cooling the molten core material by using a pump. However, the pump may not be operated when a severe accident occurs in a nuclear plant, whereby the apparatus has low reliability. Further, the cooling ability of the pump is degraded as time goes on, whereby the decay heat of the molten core material cannot be effectively removed.

Accordingly, there is required an improved apparatus for passively cooling and retaining the molten core material, which can solve the above-described problems of the related art.

[Disclosure]**AMENDED SHEET (ART. 34)**

layer formed between the outer retention vessel and the porous protection vessel, and filled with refractory gravels.

The gravels may be filled in the gravel layer to distribute and support the load of molten core material retained in the porous protection vessel.

The mixing means may include pipes connected and extended respectively from the compressed gas tank and the cooling water storage tank.

The porous protection vessel may be made by sintering refractory gravel or powder and on the inner surface of protection vessel, a layer of sacrificial and water tight material is cemented, and the outer retention vessel may have a screen layer formed on an inner surface thereof.

The cooling water storage tank may have a check valve installed at the outlet thereof so as to prevent the back flow of high-pressure gas.

The apparatus may further include an intermediate storage tank. Accordingly, steam generated by the reaction between the molten core material and the cooling water is condensed into water on the wall of the reactor containment and the condensed water is resupplied through the intermediate storage tank to the cooling water storage tank.

The intermediate storage tank may have a filter installed in an upper side thereof to filter the condensed water through the filter, whereby the filtered water is resupplied to the cooling water storage tank.

[Description of Drawings]

The above objects, other features and advantages of the present invention will become more apparent by describing the preferred embodiments thereof with reference to the accompanying drawings, in which:

FIG. 1 is a schematic view of a conventional molten core material

material retention tank 20, whereby molten core material in the molten core material retention tank 20 can be more effectively cooled due to the large contact area between the molten core material and the supplied cooling water/inert gas mixture.

As shown in FIG. 3, the passive cooling and retaining apparatus of the invention may further include an intermediate storage tank 60.

Then, when steam generated by the reaction between the molten core material and the cooling water is condensed on the inner surface of the containment building 1, the condensed water can flow along the inner surface of the containment building 1 and then down via the intermediate storage tank 60 into the intermediate storage tank 60.

In addition, the intermediate storage tank 60 preferably has a filter 61 installed in an upper side thereof to filter the condensed water. The condensed and filtered water is then recirculated via the intermediate storage tank 60 into the cooling water storage tank 40.

In this case, the intermediate storage tank 60 is connected with the cooling water storage tank 40 via a pipe 62, by which the condensed water can be resupplied via the intermediate storage tank 60 into the cooling water storage tank 40.

In this manner, the direct contact between the molten core material and the cooling water makes it possible to effectively remove the heat from the molten core material. Also, the inert gas supplied along with the cooling water can prevent steam explosion that may be generated by a violent interaction between the ultrahigh-temperature molten core material and the

cooling water, thereby making it possible to stably cool the molten core material.

Further, the invention is so designed that the steam produced through the reaction between the molten core material and the cooling water can be condensed and the condensed water can be recycled through the intermediate storage tank, by which the decay heat can be efficiently removed from the molten core material.

Furthermore, the inventive passive cooling device supplies the cooling water and the inert gas and recycles the condensed water by gravity, thereby making it possible to cool the molten core material more reliably than the conventional active cooling device using a pump.

FIGs. 4 through 6 illustrate the molten core material retention tank in detail, which will be described as follows.

Referring to FIG. 4, the molten core material retention tank 20 is connected through a coolant hole 21a with the mixer 50 of pipes, and is simultaneously supplied with the inert gas and the cooling water through the coolant hole 21a from the mixer 50, thereby cooling the high-temperature molten core material retained therein.

Here, the molten core material retention tank 20 can more effectively cool the high-temperature molten core material due to the large contact area between the molten core material and the cooling water because the cooling water/inert gas mixture is supplied to both the inner bottom and side surfaces of the molten core material retention tank 20.

Describing the structure of the invention in more detail referring to

FIGs. 4 and 5, the molten core material retention tank 20 includes an outer retention vessel 21, an inner porous protection vessel 23, and a gravel layer 22 formed between the vessels 21 and 23.

The outer retention vessel 21 includes at least one coolant hole 21a formed in a side or bottom surface thereof. The coolant hole 21a is connected to the mixer 50, whereby the cooling water/inert gas mixture is supplied through the coolant hole 21a to the molten core material retention tank 20.

The inner porous protection vessel 23 inside the outer retention vessel 21 is preferably made of sintered refractory gravels or powder so as to endure the high-temperature molten core material. Accordingly, the cooling water/inert gas mixture can smoothly flow into the molten core material retention tank 20.

The inner porous protection vessel 23 can be of several separate cylinder walls that can be assembled in a compartment structure. Also, the inner porous protection vessel 23 is made by firing refractory gravel or powder like a ceramic structure, and thus can be easily adjusted according to the shapes of the compartment. On the surface of the protection vessel, a layer of sacrificial material is cemented thick enough to provide the structural integrity and water tightness of the protection vessel 23. The sacrificial material has advantages of diluting the molten core material, having flexibility in responding to the various pattern of melt discharge from the reactor vessel. Also, as it provides water tightness of the protection vessel, inadvertent opening the valves 31, 41, and 41a during the power operation would not result in a flooding of the reactor cavity. So, any mis-operation of this invention would not have interference during the power operation of the nuclear reactor. So, it supports fully passive nature of the invention.

The porous structure of the protection vessel 23 enables the cooling water/inert gas mixture to be uniformly injected through the pores thereof into the molten core material retention tank 20, and is highly endurable against the ultrahigh-temperature molten core material, thereby potentially preventing the direct contact between the ultrahigh-temperature molten core material and a neighboring structure. Also, due to its structure, the molten

core material retention tank 20 can be removed or replaced by a new one after a severe accident.

Regarding the gravel layer 22, it is formed by filling refractory gravels 22a between the vessels 21 and 23, and thus can be easily assembled according to the shapes of the compartment.

The gravel layer 22 enables the cooling water/inert gas mixture to be uniformly injected into the molten core material retention tank 20. Also, the gravel layer 22 can store therein a predetermined amount of cooling water, thereby making it possible to more effectively cooling the high-temperature molten core material.

The gravel layer 22 is filled with the gravels 22a for supporting the weight of the molten core material retained in the porous protection vessel 23. That is, the gravels 22a of the gravel layer 22 themselves can distribute and support the weight of the molten core material. Accordingly, the present invention can support the load of the molten core material without having to use a separate supporting unit.

Also, the supply amount of the cooling water/inert gas mixture can be suitably adjusted by changing the arrangement of the coolant hole 21a and the gravels 22a.

That is, the gravel 22a size of the gravel layer 22 and the pore size of the porous protection vessel 23 can be adjusted suitably according to the size of a reactor cavity and the total amount of the molten core material, whereby the molten core material retention tank 20 can be optimally supplied with the cooling water/inert gas mixture.

FIG. 6 is a perspective view of the outer retention vessel 21 of the molten core material retention tank 20. Referring to FIG. 6, the outer retention vessel 21 preferably has a screen layer 21b formed on an inner surface thereof to border the gravel layer 22.

The screen layer 21b is designed to prevent the gravels 22a from emerging through the coolant hole 21a, and supplying the cooling water/inert gas mixture more uniformly.

An operation of the inventive passive cooling and retaining apparatus will now be described in detail with reference to FIGs. 3 through 6.

Referring to FIGs. 3 through 6, when a severe accident takes place in a nuclear plant, discharging ultrahigh-temperature radioactive molten core material from a damaged nuclear reactor into a reactor cavity, the discharged molten core material is retained in the molten core material retention tank 20 installed below the reactor vessel 10.

When the outlet valves 31 and 41 are opened, the inert gas and the cooling water respectively flow down from the compressed gas tank 30 and the cooling water storage tank 40 by pressure and gravity and are mixed in the mixer 50. The cooling water/inert gas mixture is then supplied to the molten core material retention tank 20, when the molten material discharged from the reactor vessel is accumulated enough to cause a failure of a sacrificial water tight layer on the inner surface of the protection vessel 23.

At this time, the cooling water storage tank 40 is preferably installed higher than the molten core material retention tank 20 so that the cooling water thereof can be smoothly supplied to the molten core material retention tank 20 by gravity. Also, the check valve 41a is preferably installed at the outlet of the cooling water storage tank 40 so as to prevent the back flow of

Also, a feedwater line 70 for suitably supplying feedwater is connected to the cooling water storage tank 40.

The cooling water/inert gas mixture is supplied to both the bottom and side surfaces of the molten core material by opening the outlet valves 31 and 41 before the solidification of high-temperature molten core material, whereby the molten core material is primarily cooled so that a crack-type flow channel can be formed in a solidified molten core material. Thereafter, cooling water is supplied to the crack-type flow channel of the solidified molten core material, whereby the decay heat of the solidified molten core material is removed.

As stated above, the present invention can passively supply the cooling water/inert gas mixture during the primary cooling process thereby to greatly reduce steam explosion, which may be caused by the rapid reaction between the high-temperature molten core material and the cooling water. Also, the present invention makes it possible to effectively remove the decay heat of the molten core material by passively recycling the condensed water.

Further, the present invention makes it possible to separately make and assembly the molten core material retention tank suitably according to the size of the reactor cavity, and to install the molten core material retention tank in the reactor cavity even for the existing nuclear reactor.

As sacrificial and water tight layer is cemented on the protection vessel 23, inadvertent opening the valves 31, 41, and 41a during the power operation would not result in a flooding of the reactor cavity. So, any mis-operation of this invention would not have interference during the power operation of the nuclear reactor. So, it supports fully passive nature of the invention.

Although the preferred embodiments of the present invention have been disclosed for illustrative purpose, those skilled in the art will appreciate that various modifications, additions and substitutions can be made without departing from the scope and spirit of the invention as defined in the

accompanying claims.

【Industrial Applicability】

The inventive passive cooling and retaining apparatus can prevent steam explosion by supplying the cooling water/inert mixture to both the bottom and side surfaces of the ultrahigh-temperature molten core material, thereby making it possible to greatly enhance the reliability of the cooling process.

Also, the present invention makes it possible to install the molten core material retention tank in the reactor cavity without changing the compartment structure of the containment building of the nuclear plant even for the existing nuclear reactor and it can be installed easily in the newly constructed nuclear reactor.

Further, the molten core material retention tank of this invention includes the outer retention vessel, the inner porous protection vessel, and the gravel layer formed between the vessels. Accordingly, the cooling water/inert gas mixture can be uniformly injected into the molten core material retention tank, a predetermined amount of cooling water can be stored in the gravel layer, and the gravel layer can distribute and support the weight of the molten core material.

Furthermore, the present invention makes it possible to effectively remove the decay heat of the molten core material by passively recycling the cooling water through the intermediate storage tank.

As the protection vessel with a layer of sacrificial material provides water tightness and structural integrity, any mis-operation of this invention would not have interference during the power operation of the nuclear reactor.

【CLAIMS】

【Claim 1】

An apparatus for passively cooling and retaining molten core material from a reactor, the apparatus comprising:

a molten core material retention tank installed inside a reactor cavity to retain molten core material from the reactor vessel;

a compressed gas tank having an outlet valve at an outlet thereof and supplying high-pressure inert gas;

a cooling water storage tank being installed higher than the molten core material retention tank, having an outlet valve at an outlet thereof, and supplying cooling water; and

a means for mixing inert gas supplied from the compressed gas tank with cooling water supplied from the cooling water storage tank and supplying the cooling water/inert gas mixture to the molten core material retention tank.

【Claim 2】

The apparatus of claim 1, wherein the molten core material retention tank includes:

an outer retention vessel having at least one coolant hole formed in a side or bottom thereof and connected to the mixing means;

a porous protection vessel formed of refractory material at an inside of the outer retention vessel; and

a gravel layer formed between the outer retention vessel and the porous protection vessel, and filled with refractory gravels.

【Claim 3】

The apparatus of claim 2, wherein the gravels are filled in the gravel

layer to distribute and support the load of molten core material retained in the porous protection vessel.

【Claim 4】

The apparatus of claim 1, wherein the mixing means includes pipes connected and extended respectively from the compressed gas tank and the cooling water storage tank.

【Claim 5】 (amended)

The apparatus of claim 2, wherein the porous protection vessel is made by sintering refractory gravel or powder, and on the surface of the protection vessel, a layer of sacrificial and water tight material is cemented.

【Claim 6】

The apparatus of claim 2, wherein the outer retention vessel has a screen layer formed on an inner surface thereof.

【Claim 7】

The apparatus of claim 1, wherein the cooling water storage tank has a check valve installed at the outlet thereof so as to prevent the backflow of high-pressure gas.

【Claim 8】

The apparatus of claim 1, further comprising an intermediate storage tank, wherein steam generated by the reaction between the molten core material and the cooling water is condensed into water and the condensed water is resupplied through the intermediate storage tank to the cooling water storage tank.

【Claim 9】

The apparatus of claim 8, wherein the intermediate storage tank has a

filter installed in an upper side thereof to filter the condensed water through the filter, whereby the filtered water is resupplied to the cooling water storage tank.